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April 25, 2011

Jeffrey M. Casalina
Environmental Projects Office (EPO)
U.S Department of Energy
National Nuclear Security Administration
Los Alamos Site Office
3747 West Jemez Road, MS A316
Los Alamos, NM 87544

**Subject: Los Alamos Canyon Watershed Stormwater Monitoring from 2003 through 2008: Contaminant Transport Assessment**

Dear Mr. Casalina:

This letter transmits the subject Final report. Thank you for the thorough review and thoughtful comments provided by DOE and LANL. We incorporated many of them and they enhanced the report considerably. We are also including a response to your comments for you to see how we addressed them.

If you have any questions please contact Dave Englert at 476-6022 or contact me at 661-2644.

Sincerely,

Stephen Yanicak

Stephen Yanicak, Staff Manager, /POC

SY:rf-s

Enclosure: Final Report

cc: Thomas Skibitski, Chief, DOE OB/SOS
Neil Weber, Pueblo de San Ildefonso, Office of Environmental Affairs, Director

Response to DOE and LANL comments on DRAFT Report 4-25-11

NMED Response to:
**Los Alamos National Laboratory's comments on**
**"Los Alamos Canyon Watershed Monitoring from 2003 through 2008:**
**Contaminant Transport Assessment"**
**by the Department of Energy Oversight Bureau,**
**New Mexico Environment Department**

**February 1, 2011**

## Introduction

LANL staff recognizes the amount of work and time that went into crafting of the NMED DOE OB report "Los Alamos Canyon Watershed Monitoring from 2003 through 2008: Contaminant Transport Assessment" and commends NMED staff for their efforts. In the part of the report that addresses mass transport, we have some significant concerns regarding the basis for the estimates presented.

A summary of our central concerns is summarized here and presented in more detail below. Storms on the Pajarito Plateau are typically unique, random in their track, intensity, energy, and duration. Stream flow occurs in response to these precipitation events and is by association unique in intensity, energy, and duration. Estimates of mass transport in this report should be presented with an appropriate degree of uncertainty. We look forward to discussing our comments with you in more detail at your convenience.

**NMED Response:** Thank you for the time and effort necessary to provide these comments. They will serve to improve this report. In many cases our responses have been added to the report for clarification.

We agree uncertainty should be identified and described in this report. Additional statistics were calculated and included. These statistics help demonstrate that our estimates are reasonable and reliable, and that comparison of future evaluations to these estimates and derived rating coefficients will quantify changes in the watershed.

Stream flows are unique in response to storms on the Pajarito Plateau. In part, our metrics measure the differences derived from changing flow responses to precipitation. Not only do flow characteristics respond to storms, but they reflect changing conditions within a watershed. We suggest that flow will be reduced relative to storm energies in an improving watershed, as well as sediment and contaminant transport rates. Those availabilities will diminish relative to similar flow conditions, e.g., 5000 mg/L SSC at 100 cfs relative to improved watershed conditions of 500 mg/L SSC at 100 cfs.

## General comments:

1) The term correlation coefficient is used throughout the report to refer to the slope coefficient in a linear regression model ($y = mx+b$, where m is the slope coefficient). The coefficient of determination ($R^2$) is the square of the correlation coefficient (R).

**NMED Response:** Our use of the term correlation coefficient is incorrect. The term rating coefficient will be used where appropriate to describe the derived slope coefficient.

To be clear, two rating coefficients are developed within this report; a rating coefficient that describes the relation between instantaneous discharge and plutonium and/or suspended sediment concentrations; and a rating coefficient that describes the relation between peak discharge and mass inventories of plutonium and/or sediments transported during a storm event. We will change these references to Concentration Rating Coefficient and Inventory Rating Coefficient where appropriate.

Refer to the sections "Event Transport of Plutonium and Sediment" and "Station Transport of Plutonium and Sediment" pages 16 through 23 for complete details regarding development of these rating coefficients.

2) For the storm-event-based relationships developed between plutonium-239 concentrations and discharge, and suspended sediment concentrations and discharge (Appendix C), very few (1 to 4) data points were used, leading to very low confidence levels and significance. More detailed statistics should be presented for each of the linear relationships, perhaps a table with storm event date, number of data points, degrees of freedom, student t-test statistic, p values, confidence levels, etc. Also, when using these relationships to predict plutonium and sediment transport, error bars should be presented along with the predictions.

**NMED Response:** Table C-1. Storm-Event-Based Statistics has been added to the end of Appendix C. It includes sample numbers per event, degrees of freedom, peak flow, the Pearson product moment correlation coefficient describing both the plutonium/flow and sediment/flow relationships, and the p values describing the correlation significance and slope coefficients of both relationships.

It should be noted that the Storm-Event-Transport evaluations were based on assumptions that sediment and contaminant concentrations increased proportionately with increasing flow. These assumptions were developed from empirical measurements in previous reports and a few well characterized events during the period of this report. It was not the intent of this report to fully characterize every event, but use the assumptions and samples collected during an event to estimate its sediment and contaminant transport.

3) Using the output from one model (predicted concentrations over a storm event based on the linear regression model of plutonium and suspended sediment concentrations with respect to discharge) as input into another model (the linear regression model of total plutonium and sediment volumes with respect to peak discharge) will compound errors, which should be included when presenting any data.

**NMED Response:** In addition to the statistics noted in comment 2, we've included a statement in the introduction that "uncertainty is associated with these estimates but not quantified in this report. All measurements contain uncertainty. Environmental surveillance measurements contain uncertainty from multiple sources, including sampling, chemical analysis, and the inherent variability in the environment. Our estimates potentially contain the same sources of uncertainty compounded and propagated through multiple iterations of the transport estimate process."

We recognize this contains uncertainty, but suspect estimates error on low side.

Evaluations completed for only events greater than 10 cfs, have not included

1. Or compensated for multiple surges or long duration floods more common during large autumn frontal storm systems
2. Complete events, some which flow at low discharge for days. Only the major, high-discharge, quick-changing portion of the events that last for hours were evaluated
3. Bedload estimates
4. Snowmelt, generally less than 10 cfs but flow can be continuous for months
5. Discharge from Pueblo Canyon Treatment plant
6. Estimates for storm events not gauged

Also see page 19 paragraph 4 that describes uncertainty sources, including provenance, and development of ranges for estimates.

4) Antecedent conditions can influence suspended sediment concentrations significantly. For example, a storm event the previous day can effectively "clean" a channel, producing changes in the suspended sediment/discharge relationship. This should be taken into account or noted when using general relationships to relate suspended sediment concentrations to discharge.

**NMED Response:** Yes, particularly in low flow storm events in which case relatively small inventories of sediment and contaminants are transported. In larger events, we believe that antecedent conditions are reflected by hysteresis observed during the rising leg of a hydrograph, whether it is from the cleaning affects as mentioned above or bank failure contribution from preceding events. This period of the hydrograph is relatively short in relation to the flood duration. By the time peak flows are achieved antecedent conditions are replaced by the overall conditions of a channel reflected by the general relationship of suspended sediment concentrations and discharge.

Along with peak flow, we evaluated rate of travel within the watershed, flood duration, and time to peak flow from the flood bore. Based on these observations and an assumption that most of the floods within the ephemeral LA watershed are "flashy" we included delays in our sample programs to begin sampling shortly after the peak flow of a flood passes and then to collect at regular intervals during the remainder of the flood. This allowed us to accurately characterize transport within the greatest proportion of the flood.

5) Inaccuracies can be introduced by developing plutonium, suspended sediment concentrations, and peak discharge relationships based on data six to seven years after the Cerro Grande fire, then applying the relationship to data shortly after the fire (e.g. for station E055, page 22). The watersheds have changed significantly during this time period. Also, applying relationships developed for one year to previous and future years can introduce error (e.g. for station E030, page 24).

**NMED Response:** In some ways that is the point of this report, applying relationships developed for one year or station to the evaluations of following years or stations may be useful in monitoring changes in the watershed. If LANL mitigations in the watershed are successful, we expect to see the "Inventory Rating Coefficient" and therefore the sediment and contaminant availability to decline over the years. Regardless of the inaccuracies contained in the report based on data from the six to seven years after the fire, we suspect that the watershed has demonstrated continuing improvement, the coefficients represent the latest average available data, and that watershed improvements will continue if not accelerate.

We suspect future "Concentration Rating Coefficients" may contain greater variability, but they should also decline.

6) The linear regressions for plutonium, suspended sediment concentrations, and peak discharge were performed on data within a certain range. There is no statistical foundation to extrapolate this relationship to very large discharge values, and can introduce a significant amount of error. For example, the 1780 and 1179 CFS flows at E055 are very large (and comprise 69% of the total suspended sediment and contaminant loads, page 22-23), yet the linear relationship was based on flows ranging from 0.71 to 45 CFS.

**NMED Response:** We agree that an extrapolation to the 1780 and 1179 cfs values at E055 could introduce a significant amount of error in the sediment transport estimates as demonstrated by evaluations at E050, E060, and E110. At these locations we had been successful in sample collection from the extraordinarily large floods that occurred during the period of this report and found that concentrations of sediment and contaminants increased proportionately with flow, although the proportions may have increased at different rates.

We evaluated this variability be two methods, in one we developed ranges of contaminant and sediment transport inventory, and in the other we developed an inventory estimate based on a piecewise linear approximation. For example, at E050 we suggest that a range of 576 to 755 tons of sediment was transported from 2003 to 2008. But we also suggested that a better sediment transport approximation may be 727 tons based on a piecewise assessment. We made the similar range and piecewise estimates at E060 and E110. At E030 and E042 extrapolations were also made, but the discharge differences were not as large as seen at E055. We also indicated that E042 contained very limited information and was presented for comparison only.

Although a range was not made for E055; the contaminant load, the inventory rating coefficients, and gross concentrations of plutonium in sediments, all derived from the extrapolation appear to substantiate the fairly low estimates that might be expected for a station located above probable LANL impacts. These data appear to reflect background conditions well and became useful reference information.

7) Many references are made to the fact that the slope coefficient indicates the amount of plutonium and sediment available for transport. It is the range of plutonium and sediment values that indicate the amount available for transport.

**NMED Response:** The difference we make is that plutonium and sediment values of concentration in water, pCi/L or mg/L, define the instantaneous mass relationship to volume of water. In our report, the rating coefficients define the relationship of plutonium or sediment to flow, L/s. If that relationship is defined for an event, the "concentration slope coefficient" can be used to predict an instantaneous concentration based on flow. Cumulative mass transport can then be calculated over time from changing flow through the event.

If the slope coefficient changes over time, we can conclude that sediments and/or contaminants are being transported at different rates. Future floods through an improving watershed capable of trapping more sediment would generate a smaller concentration slope coefficient. Inventory slope coefficients are developed similarly. These coefficients can be compared through time or space to identify differences in availability.

Also refer to the Temporal and Spatial Changes sections, pages 60 to 78, regarding the range of concentration measurements and discussion.

8) Attention should be paid to the provenance of storms and sediments as shown by the August 15 and 16, 2010 flow events at 109.9. Sediments were mainly derived from the hill slope north and adjacent to the Totavi store; a region not impacted by laboratory processes (background Pu). This would result in lower concentrations of Laboratory derived contaminants.

**NMED Response:** This may be a particularly important consideration for users of the Buckman Direct Diversion. We suggest there may be differences in contaminant levels that originate from Pueblo, upper to mid Los Alamos, lower Los Alamos, and Guaje Canyons. Please refer to the "*Station Transport of Plutonium and Sediment - Station E110*" section, page 40 through 48, and "*Runoff Origin at E110*" section, starting page 57 that discuss in detail contaminant concentrations derived from different source terms as well as how these methods dealt with the differences. Flood origin from upper Los Alamos and DP Canyons are also considered for stations E042 and E050. We noted little effects from flood origin at stations E055 and E030 regarding concentration and transport of contaminants or sediments.

At station E060, research into provenance for storms during four events could have been useful, August 22, 2003, August 20, 2004, July 26, 2006, and August 6, 2007. These storm discharges range from less than 1 cfs to 50 cfs but delivered sediment containing relatively low plutonium concentrations compared to the remaining 15 events we had evaluated.

LANL should consider maintaining and monitoring gages at E090 Guaje Canyon and potentially installing a new gage in lower Los Alamos Canyon above the Guaje Canyon confluence.

9) Hydrographs are quite different in and reflect the unique characteristics of each storm event. In some cases three to four assessments of sediment/Pu relationship were used to calculate sediment transport in flow events without samples without any mention of error or underlying assumptions of storm track or character.

**NMED Response:** See response to comments 2, 4, and 8.

The hydrographs generated within the ephemeral streams of the Pajarito Plateau, including the Los Alamos watershed are generally considered "flashy". Storm surges typically generated hydrographs that illustrated fairly quick rises to peak discharge and then slower declining limbs. While we agree storm intensity, duration and movement of storm patterns, and drainage basin characteristics produce variations in flood hydrographs, those variations are most pronounced between the frequent summer monsoonal events that produce short-lived and intense floods relative to the infrequent autumn large-frontal system rainfall that produce longer, broader, and less intense floods.

Most of the events evaluated during this report period are from the monsoonal events that produced short flood durations relative to their peak flow. Although, using those metrics for subsequent events that generate longer duration floods with multiple peak surges would under-estimate transport inventories, we believe our estimates are reasonable.

Although the evaluations were not presented in this report, we evaluated storm hydrographs at the end of each sample event, and then the end of each season to determine the peak discharge, time to peak flow, and then duration of the storm flow event. Based on these evaluations we developed our sampling programs to collect soon after the peaks of the storm surges and at regular intervals during the event. Many of these evaluations can be noted in Appendix C, the *Individual Inventory Transport Evaluations*, and Appendix D, *Hydrographs* that extend from 2003 to 2008 for E060, E050, and E110 as well as the maximum annual flows for most Los Alamos watershed gage stations.

Additional statistics have been developed that define the significance of the relationships developed and used to make our estimates.

10) No assumptions or basis for models is presented or justified.

**NMED Response:** The following assumptions are condensed from the "Event and Station Transport of Plutonium and Sediment" sections, pages 16 through 21, and included in the Introduction section.

The following transport estimates were made from assumptions developed by observation and empirical measurements in stormwater since the Cerro Grande fire. General assumptions we found true were that suspended sediment concentrations in stormwater increase and decrease proportionately with flow rates, that plutonium concentrations in suspended sediments were fairly consistent at individual stations, and total plutonium measurements in water increased uniformly with suspended sediment concentrations. Based on these assumptions and the correlations between stormwater flow rates and suspended sediment and plutonium concentrations, we estimated sediment and plutonium contaminant transport in individual storm events and then for all events at each gage station we monitored in the Los Alamos watershed.

11) No mention is made of the relationship between storm energy, sediment size, and sediment surface area. Pu is primarily attached to sediments; the amount, grain size, and surface area are dependent upon the character of the flow event (hydrograph).

**NMED Response:** We agree that plutonium, as well as other insoluble contaminants, are primarily attached to sediments. We also recognize that these contaminants have a propensity to adhere to finer grained sediments due to greater surface area and chemical and physical bonding. Although particle size measurements were not made, we recognize and propose two assumptions;

- the great majority of sediments carried in the water column of storm flows are fine grained silt and clay materials
- that some variability in suspended sediment and plutonium measurements may originate from the size assortment of materials within the storm flow.

We did introduce and test a hypothesis that coarse grained sediments would drop out of storm flows within the impoundment formed by the low head weir in Los Alamos Canyon. We also suggest this may occur within the wetlands in Pueblo Canyon. This action might reduce and "fine" suspended sediments, enriching plutonium in the sediments, and thereby increasing total plutonium concentrations in water. Our measurements did suggest an enrichment of plutonium in stormwater at E050 and an overall reduction in the stormwater contaminant load, although more measurements are required at the new E042.1, E050.1, E059, and E060.1 stations to substantiate and quantify the affects.

12) Rad data qualifier codes need to be presented and described in the appendix.

**NMED Response:** Yes, this is an oversight and qualifier codes will be added to the end of the chemical data tables in Appendix A.

13) A samples taken table would be helpful to understand what samples were collected at each location and when.

**NMED Response:** Table 1. "Location, Date, and Time for All Stormwater Samples" is located on page 12. Chemical analysis for each sample is in Appendix A and a narrative of the analytical suites and samples is found in the section "Samples and Analytical Suites". We will develop an additional table (Table B.1.) in Appendix B that summarizes the analysis suites for each station.

14) Rating tables used to calculate flow should be in an appendix as well as cross sections and channel slope measurements.

**NMED Response:** Although we measured cross sections, slopes, and roughness at most locations, we found that our flows rarely correlated to LANL gage measurements. Early into our stormwater monitoring efforts we abandoned our discharge measurements. We used our flow meters to initiate sample collection based on stage only. Flow measurements are based almost entirely on LANL gages and their rating curves. See page 6.

15) No precipitation data is presented or discussion about storm intensity, track, or duration for any flow events. This information is important to determine origin of runoff such as town site, laboratory, or watershed provenance.

**NMED Response:** We also believe that precipitation data is important in some context, but our evaluations are based on the flow and concentrations measured at each station. Contaminant and sediment transport estimates are made in regard to the immediate measurements at each LANL gage station monitored during the period of this report. Those estimates clearly describe impacts from upstream reaches and contaminant contributions to downstream reaches in the Los Alamos watershed.

Discussion is presented that regards provenance based on differences in contaminant concentrations and transport (we commonly refer to provenance as flood origin in this report). See responses to comments 8 and 9. We also provided detailed discussion regarding flow between stations in the "Flow Evaluation" section page 51.

See also Background section starting page 4, the Flow Evaluation Section starting on page 51, and Appendix D the Hydrograph section starting page 191 for additional discussion regarding precipitation, provenance, and other relationships to discharge sources.

16) LANL and NMED both agree that correlations between peak flow and mass transport are very poor. At E060, even when correlations are good, equations describing the flow range from 1.9993 x to 0.0327 x, a difference of 2 orders of magnitude. Because of this we would like to see a more robust development of the equations used to describe the storms that were not sampled. In addition, a measurement error should be developed and applied to each mass transport calculated.

**NMED Response:** NMED does not agree that the correlations between peak flow and mass transport are "very poor". By conventional criteria most correlations between peak flow and plutonium and sediment mass transport evaluations in this report are considered extremely significant. The only correlations of questionable use are those at E042. As stated in the "*Station Transport of Plutonium and Sediment*" section for station E042, page 26 "*the number of samples* (at E042) *is inadequate to describe the conditions of the watershed here,* (although) *they begin to provide values similar to what we expected. Additional sampling would be required to characterize this assessment more fully*".

The correlations between instantaneous flow and plutonium and sediment concentrations for individual storm events that our preliminary assumptions are based on are also considered significant. Although, we recognize many storm events did not contain data from a large number of samples, we base our conclusions on the assumptions derived from multiple well characterized events.

For the comment regarding E060, it's unclear where the LANL reference to values 0.0327 or 1.9993 came from. We evaluated plutonium mass and peak flow, deriving two equations used to predict plutonium transport mass for storm events not sampled. The equations were $y = 0.037x$ and $y = 0.0188x$, where y is the predicted plutonium mass measured in mCi and x is measured peak flow in cfs. We made both of these evaluations because of the large difference between a near 2000 cfs peak flood and the next largest flood of 600 cfs. The 2000 cfs flood could potentially be over influential to the correlation. Based on these evaluations, we estimated that the transport mass ranged from 208 mCi to 305 mCi. We also estimated a more likely value of 246 mCi using a piecewise method. We believe these values to be reasonable.

17) The transport results are presented as if they are actually determined when they are really very rough estimates at best.

**NMED Response:** We actually did determine them and believe they are the best available estimates. We believe they are reasonable and reliable enough that when used as references, future monitoring measurements will quantify changes in the watershed.

**Particular comments:**

1) Page 18, paragraph 4, last sentence: how did you generate a range of inventory transport to compensate for uncertainty at E060?

**NMED Response:** See response to comment 6. We generated two equations that describe the relationship between peak flow and transport. Using two equations developed a range estimate to compensate for a potentially over influential flow to the correlations. Based on these evaluations, we estimated that between 208 mCi to 305 mCi of plutonium was transported beyond E060 since the Cerro Grande fire.

2) Table 4 is confusing with respect to what is meant by factor. Is factor the slope coefficient for the rating curve? Should specify which factor is which.

**NMED Response:** See comment 1. Yes, we were referencing two rating curves with slope coefficients. We will change these references to Concentration Rating Coefficient and Inventory Rating Coefficient where appropriate.

3) Page 42, paragraph 2, third sentence: why is a relationship for E050 applied to E110?

**NMED Response:** See comment 8 and 15. We used the E050 plutonium/peak-flow rating-curve-correlation coefficient at E110 for floods that originate from Los Alamos Canyon above E050. Inventory coefficients were also developed from flows at E110 for floods that originated from Guaje as well as Pueblo Canyons. We believe these evaluations addressed flood provenance. Please also review page 48 regarding origin of contaminant transport at E110.

4) Page 56, paragraph 2, fifth sentence: if 62 of 76 events resulted in 100% transmission loss between E050/E060 and E110, what is the reason it seems unlikely? Also, applying an average transmission loss for fourteen events to 62 events seems more inaccurate.

**NMED Response:** We often found gage operation at E110 unreliable; refer to Appendix D, the annual hydrographs for E110. We also collected samples from several events not recorded by the gage. At least six events (8/20/2008, 8/21/2008, 7/6/2006, 7/17/2005, 8/20/2004, and 8/19/2004) were sampled but discharge measurements were not recorded, or recorded as zero. The following sentence in the text also described two events when flow was measured in hundreds of cubic feet per second at upstream stations E050 and E060 but were not measured at E110. We found it likely that flow records at E110 were incomplete particularly during some of the 62 events recorded at E050 and E060.

We expect that the average transmission loss presented here is inaccurate. Besides incomplete records at E110, other factors such as provenance, flow, alluvial saturation, and other channel conditions contribute to a varied transmission loss factor. We presented the value as a reference for potential flows at E110, although we suspect that a thorough evaluation of transmission losses could be used for monitoring watershed health and should be investigated further.

5) Page 59, paragraph 4, and second sentence: regarding the statement, "if suspended sediment concentrations increase or decrease so do the plutonium concentrations in water," the sediment size distribution also needs to be taken into account.

**NMED Response:** Sediment size distribution does contribute to the variability in plutonium concentrations in water, although in measurements of these magnitudes generated in separate reaches across the watershed (where for example plutonium in sediments from background source terms are less than 1 pCi/g relative to plutonium in sediments from impacted source terms that are near 10 pCi/g) we suspect the greatest source of variability is derived from source term. A temporary change in source of suspended sediments might vary from high flow overbank floods to low volume floods transporting bank failure sediments, or other antecedent conditions.

We believe the greatest majority of the suspended sediments are silts and clays. In 2002 we collected 20 storm water samples at four Pueblo Canyon locations from five storm flow events. The average content of silt and clay was 94.8% with a 5.9% standard deviation. Total silt and clay content ranged from 81.6% to 99.8%. Also, a regression analysis of SSC and plutonium values for 88 values collected in Pueblo Canyon E060 during the period of this report indicates that the correlation is considered to be extremely statistically significant. $P = 0.0001$, $r = 0.694$, $df = 86$.

In the context of this section, we demonstrated the relation between suspended sediment, plutonium measurements in sediment, and plutonium measurements in water. Of particular significance are the magnitudes of plutonium values in sediment and the relation it bears on plutonium measurements in water. For example, stormwater from Acid Canyon typically contains suspended sediment that has large values of plutonium measured in it; the average of 17 pCi/g was calculated from samples taken for this report. Yet because Acid Canyon contributes relatively small amounts of suspended sediment to storm water, an average of 2000 mg/L, a relatively small downstream contribution of contaminants is made. The average plutonium concentration in water from Acid Canyon is 29 pCi/L, while other stations just downstream in Pueblo contain total plutonium values in water that exceed 100 pCi/L.

6) Page 140, App C, Event on 8/22/2003 at Station E060, measured and predicted labels are switched in legend of SSC Flow Correlation graph.

**NMED Response:** Thank you, it will be corrected.

7) Page 171, App C, Event on 8/8/2006 at Station E050, measured is labeled as "Series1" in legend of Plutonium Flow Correlation graph.

**NMED Response:** Thank you, it will be corrected.